Figure 1

Publication	PECVD Reaction	Delta-n Control Method	Post-dep. Thermal Treatment (°C)
Valette S.,1987	Unknown	P doping	Not specified
Valette S.,1988	**Unknown**	**P doping**	**400°C**
Grand G., 1990	Unknown	P doping	1000°C
Liu K., 1995	Unknown	Content in Si, P	Not specified
Ojha S., 1998	Unknown	Ge, B, or P doping	Not specified
Canning J., 1998	Unknown	Ge doping	Not specified
Bulla D., 1998	TEOS	TEOS	Not specified
Johnson C., 1998	**$SiH_4 + O_2$**	**Si ion Implantation**	**400°C**
Boswell R. W., 1997	$SiH_4 + O_2$	SiH_4/O_2 flow ratio	1000°C
Bazylenko M. V., 1995	$SiH_4 + O_2 + CF_4$	$(SiH_4+O_2)/CF_4$ flow ratio	Not specified
Bazylenko M. V., 1996	$SiH_4 + O_2 + CF_4$	$(SiH_4+O_2)/CF_4$ flow ratio	1000°C
Durandet A., 1996	**$SiH_4 + O_2 + CF_4$**	**$SiH_4/O_2/CF_4$ flow ratio**	**100°C**
Kapser K., 1991	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1060°C
Lai Q., 1992	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1100°C
Lai Q.,1993	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1100°C
Pereyra I., 1997	**$SiH_4 + N_2O$**	**SiH_4/N_2O flow ratio**	**400°C**
Alayo M., 1998	$SiH_4 + N_2O$	SiH_4/N_2O flow ratio	1000°C
Kenyon T., 1997	$SiH_4 + N_2O + Ar$	$SiH_4/N_2O/Ar$ flow ratio	1000°C
Lam D. K. W., 1984	$SiH_4 + N_2O + NH_3$	$SiH_4/N_2O/NH_3$ flow ratio	Not specified
Bruno F., 1991	$SiH_4 + N_2O + NH_3$	$SiH_4/N_2O/NH_3$ flow ratio	1100°C
Yokohama S., 1995	$SiH_4 + N_2O + NH_3$	$SiH_4/N_2O/NH_3$ flow ratio	Not specified
Agnihotri O. P., 1997	**$SiH_4 + N_2O + NH_3$**	**$SiH_4/N_2O/NH_3$ flow ratio**	**700-900°C**
Germann R., 1999	$SiH_4 + N_2O + NH_3$	Unknown	1100°C
Offrein B., 1999	$SiH_4 + N_2O + NH_3$	Unknown	1150°C
Hoffmann M., 1995	$SiH_4 + N_2O + NH_3 + Ar$	$SiH_4/N_2O/NH_3/Ar$ flow ratio	Not specified
Hoffmann M., 1997	$SiH_4 + N_2O + NH_3 + Ar$	$SiH_4/N_2O/NH_3/Ar$ flow ratio	Not specified
Tu Y., 1995	$SiH_4 + N_2O + NH_3 + N_2$	$N_2O/(N_2O + NH_3)$ flow ratio	1050°C
Poenar D., 1997	$SiH_4 + N_2O + NH_3 + N_2$	$SiH_4/N_2O/NH_3/N_2$ flow ratio	850°C
Ridder R., 1998	$SiH_4 + N_2O + NH_3 + N_2$	$SiH_4/N_2O/NH_3/Ar$ flow ratio	1100°C
Worhoff K., 1999	$SiH_4 + N_2O + NH_3 + N_2$	$SiH_4/N_2O/NH_3/N_2$ flow ratio	1150°C
Bulat E.S., 1993	**$SiH_4 + N_2O + N_2 + O_2 + He + CF_4$**	**$SiH_4/(N_2O/N_2)/O_2/CF_4$ flow ratio**	**425°C**
This Patent Application	**$SiH_4 + N_2O + PH_3 + N_2$**	**Patented Pending Method**	**650°C**

Figure 2

	H-OH	H-OS	H-NS	H-NS	H-S	O=S	N=N	S-OS	S-OS	S-ON	S-OH	S-OS	S-OS
Min	3550	3470	3380	3300	2210	1800	1530	1080	1000	910	860	740	410
Ave	3650	3510	3420	3380	2260	1875	1555	1180	1080	950	885	810	460
Max	3750	3550	3460	3460	2310	1950	1580	1280	1160	990	910	880	510
Min	2.817	2.882	2.959	3.030	4.525	5.556	6.536	9.259	10.000	10.989	11.628	13.514	24.390
Ave	2.740	2.849	2.924	2.959	4.425	5.333	6.431	8.475	9.259	10.526	11.299	12.346	21.739
Max	2.667	2.817	2.890	2.890	4.329	5.128	6.329	7.813	8.621	10.101	10.989	11.364	19.608
Min	1.408	1.441	1.479	1.515	2.262	2.778	3.268	4.630	5.000	5.495	5.814	6.757	12.195
Ave	1.370	1.425	1.462	1.479	2.212	2.667	3.215	4.237	4.630	5.263	5.650	6.173	10.870
Max	1.333	1.408	1.445	1.445	2.165	2.564	3.165	3.906	4.310	5.051	5.495	5.682	9.804
Min	0.939	0.961	0.986	1.010	1.508	1.852	2.179	3.086	3.333	3.663	3.876	4.505	8.130
Ave	0.913	0.950	0.975	0.986	1.475	1.778	2.144	2.825	3.086	3.509	3.766	4.115	7.246
Max	0.889	0.939	0.963	0.963	1.443	1.709	2.110	2.604	2.874	3.367	3.663	3.788	6.536
Min	0.704	0.720	0.740	0.758	1.131	1.389	1.634	2.315	2.500	2.747	2.907	3.378	6.098
Ave	0.685	0.712	0.731	0.740	1.106	1.333	1.608	2.119	2.315	2.632	2.825	3.086	5.435
Max	0.667	0.704	0.723	0.723	1.082	1.282	1.582	1.953	2.155	2.525	2.747	2.841	4.902
Min	0.563	0.576	0.592	0.606	0.905	1.111	1.307	1.852	2.000	2.198	2.326	2.703	4.878
Ave	0.548	0.570	0.585	0.592	0.885	1.067	1.286	1.695	1.852	2.105	2.260	2.469	4.348
Max	0.533	0.563	0.578	0.578	0.866	1.026	1.266	1.563	1.724	2.020	2.198	2.273	3.922
Min	0.469	0.480	0.493	0.505	0.754	0.926	1.089	1.543	1.667	1.832	1.938	2.252	4.065
Ave	0.457	0.475	0.487	0.493	0.737	0.889	1.072	1.412	1.543	1.754	1.883	2.058	3.623
Max	0.444	0.469	0.482	0.482	0.722	0.855	1.055	1.302	1.437	1.684	1.832	1.894	3.268
Min	0.402	0.412	0.423	0.433	0.646	0.794	0.934	1.323	1.429	1.570	1.661	1.931	3.484
Ave	0.391	0.407	0.418	0.423	0.632	0.762	0.919	1.211	1.323	1.504	1.614	1.764	3.106
Max	0.381	0.402	0.413	0.413	0.618	0.733	0.904	1.116	1.232	1.443	1.570	1.623	2.801
Min	0.352	0.360	0.370	0.379	0.566	0.694	0.817	1.157	1.250	1.374	1.453	1.689	3.049
Ave	0.342	0.356	0.365	0.370	0.553	0.667	0.804	1.059	1.157	1.316	1.412	1.543	2.717
Max	0.333	0.352	0.361	0.361	0.541	0.641	0.791	0.977	1.078	1.263	1.374	1.420	2.451

Figure 3a

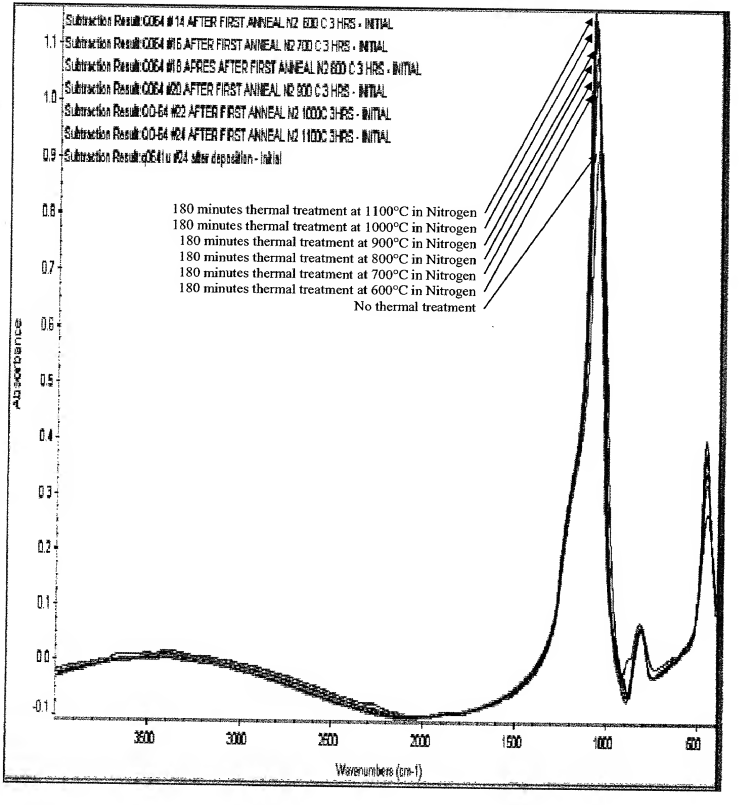


Figure 3b

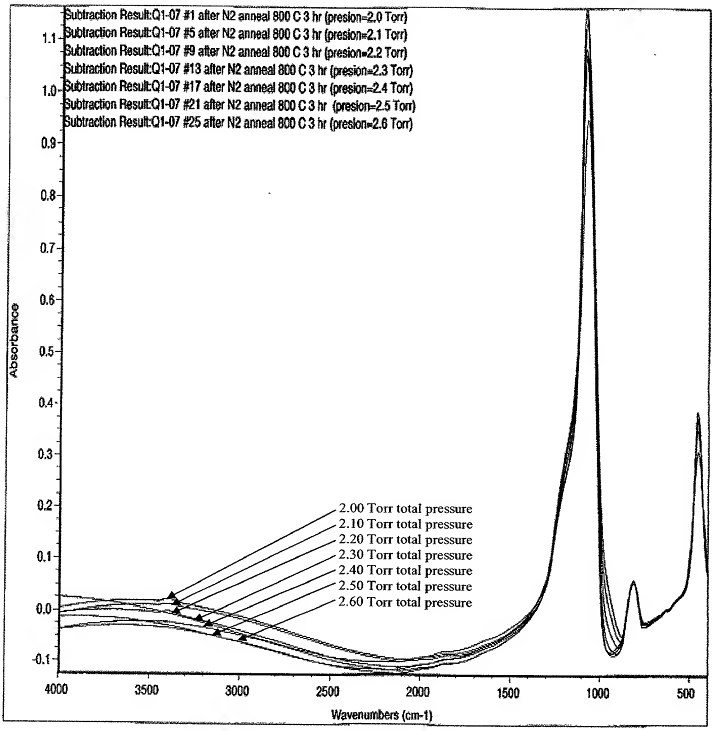


Figure 3c

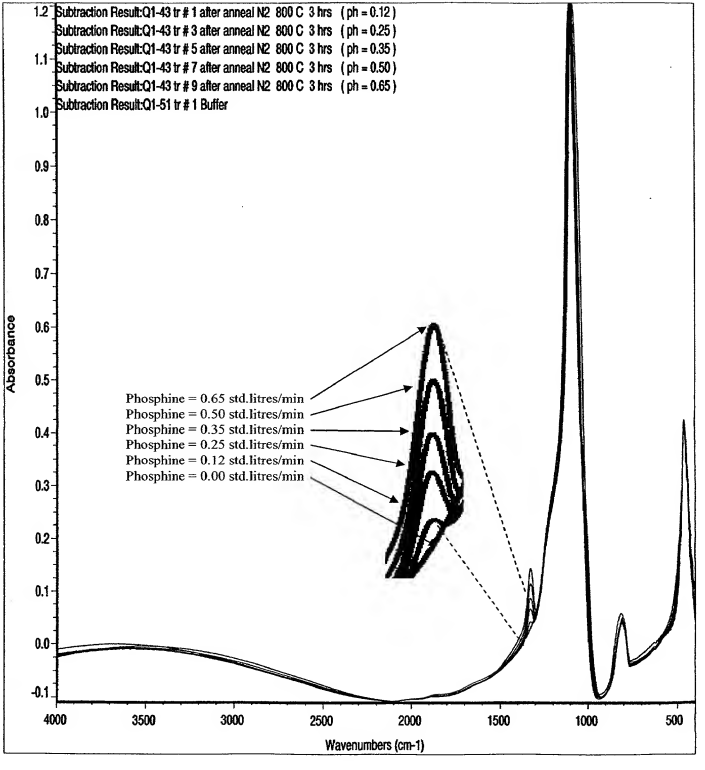


Figure 3d

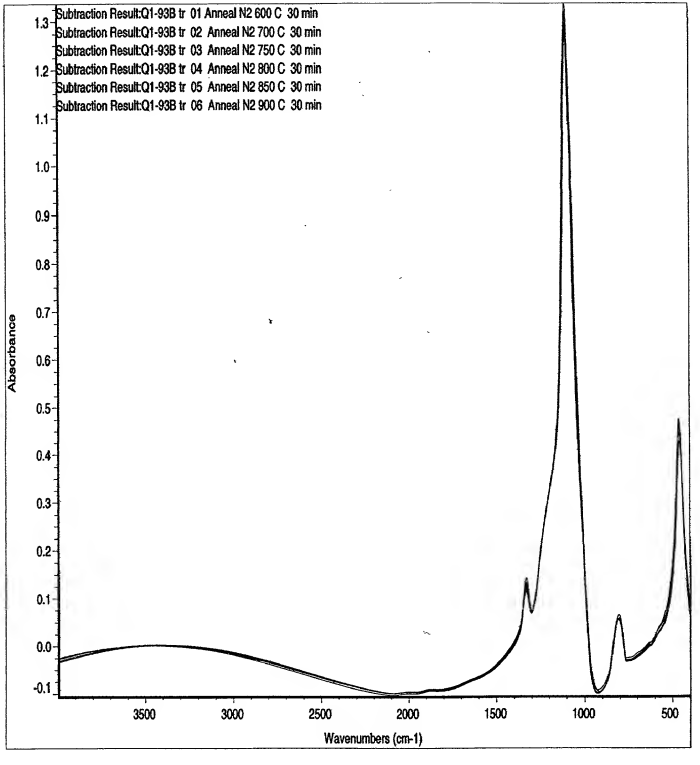

Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
Absorbance
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
3500
3000
2500
2000
1500
1000
500
Wavenumbers (cm-1)

Figure 4a

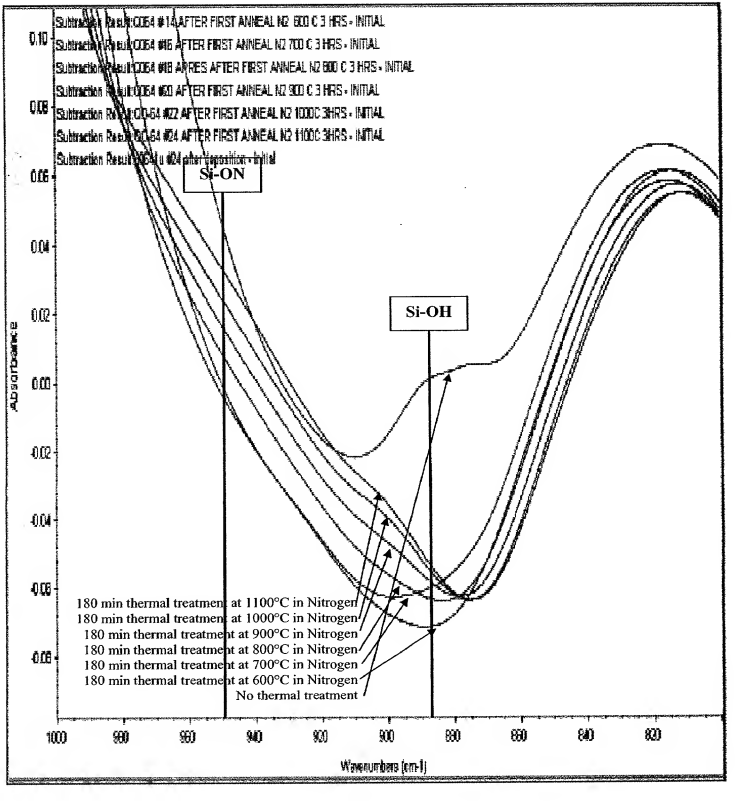


Figure 4b

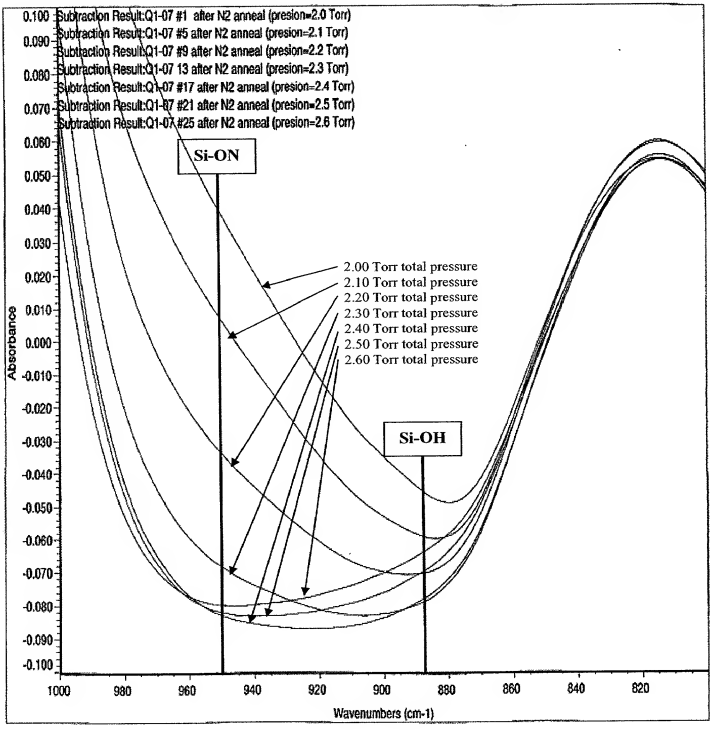

Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
Si-ON
Si-OH
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
Absorbance
Wavenumbers (cm-1)

Figure 4c

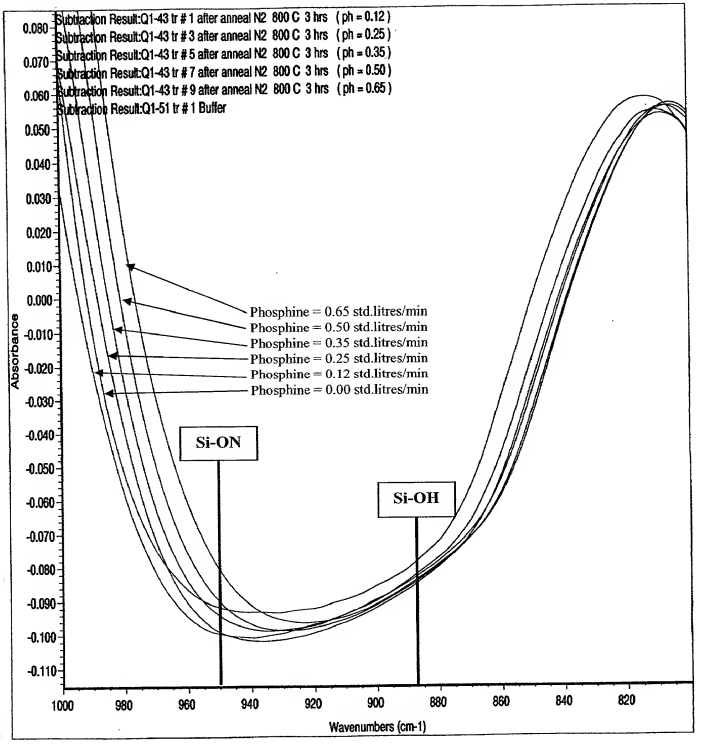

Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
Phosphine = 0.65 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.00 std.litres/min
Si-ON
Si-OH
Absorbance
Wavenumbers (cm-1)
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
-0.010
-0.020
-0.030
-0.040
-0.050
-0.060
-0.070
-0.080
-0.090
-0.100
-0.110
1000
980
960
940
920
900
880
860
840
820

Figure 4d

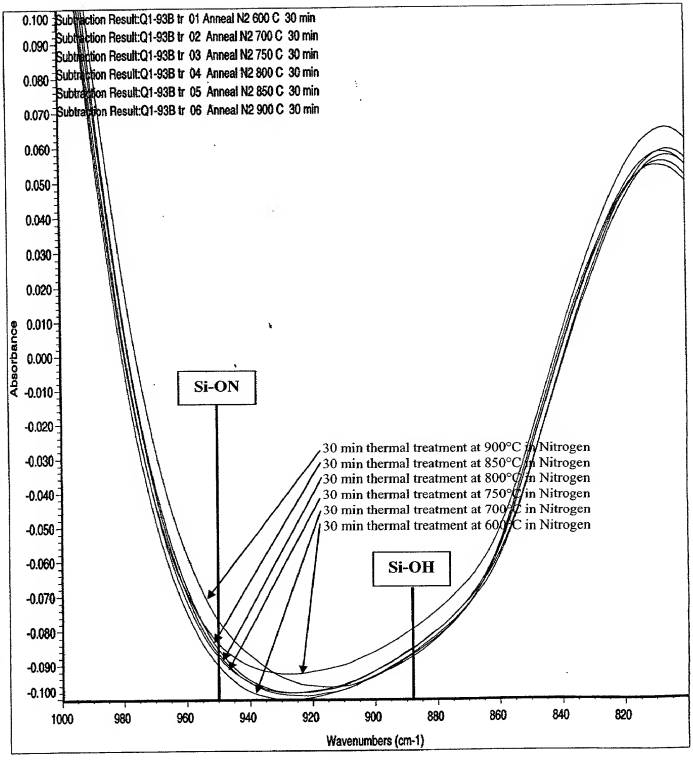

Subtraction Result:Q1-93B tr 01 Anneal N2 600 C 30 min
Subtraction Result:Q1-93B tr 02 Anneal N2 700 C 30 min
Subtraction Result:Q1-93B tr 03 Anneal N2 750 C 30 min
Subtraction Result:Q1-93B tr 04 Anneal N2 800 C 30 min
Subtraction Result:Q1-93B tr 05 Anneal N2 850 C 30 min
Subtraction Result:Q1-93B tr 06 Anneal N2 900 C 30 min
Absorbance
Wavenumbers (cm-1)
Si-ON
Si-OH
30 min thermal treatment at 900°C in Nitrogen
30 min thermal treatment at 850°C in Nitrogen
30 min thermal treatment at 800°C in Nitrogen
30 min thermal treatment at 750°C in Nitrogen
30 min thermal treatment at 700°C in Nitrogen
30 min thermal treatment at 600°C in Nitrogen

Figure 5c

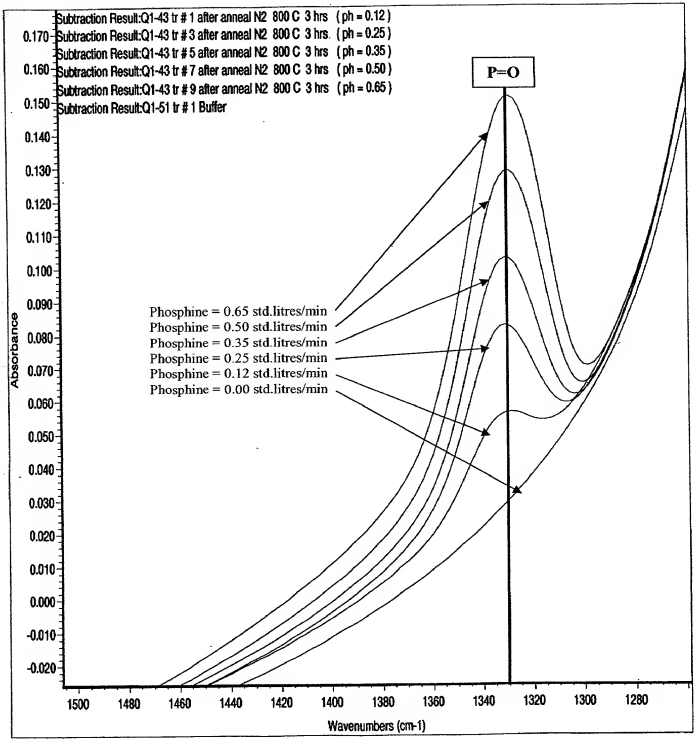


Figure 5d

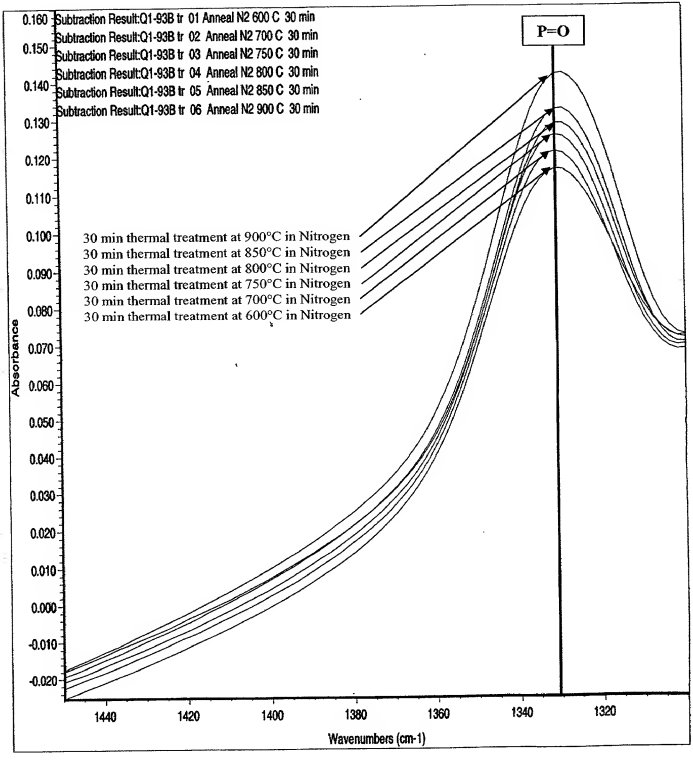


Figure 6a

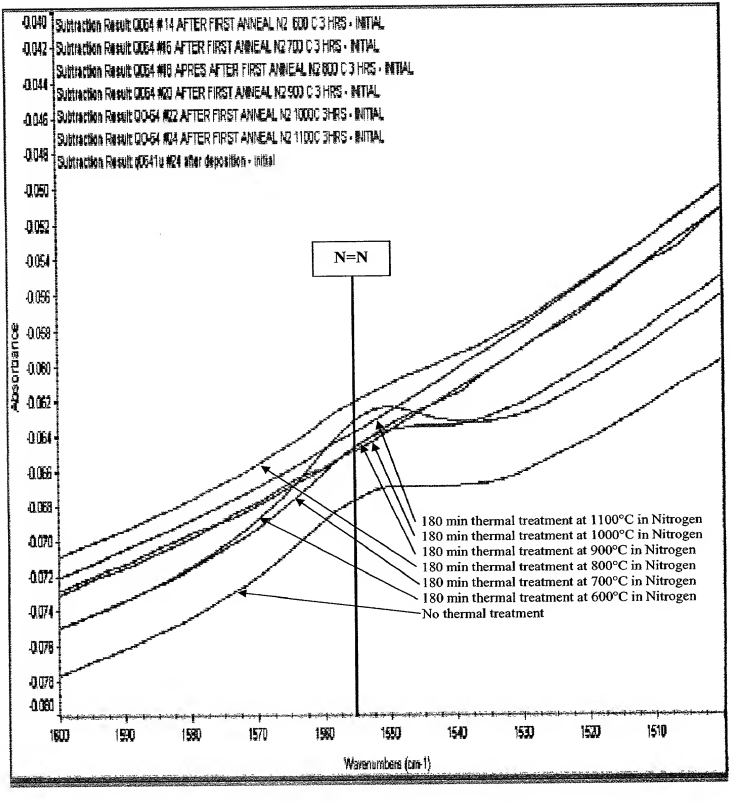


Figure 6b

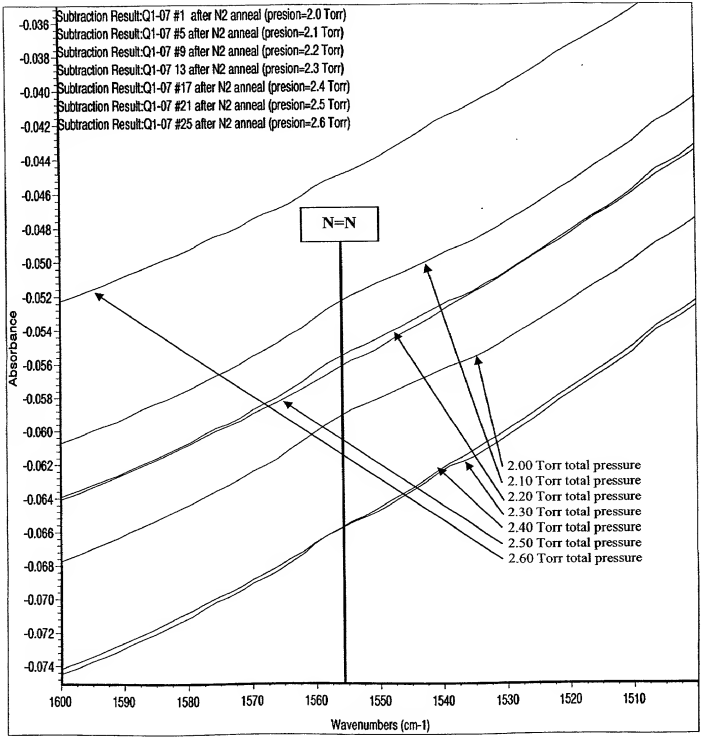


Figure 6c

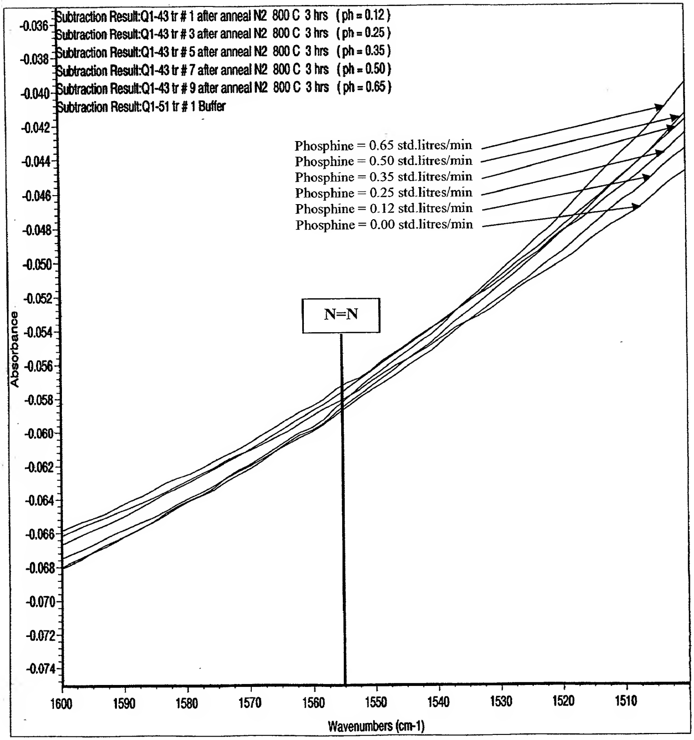

Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
Phosphine = 0.65 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.00 std.litres/min
N=N
Absorbance
-0.036
-0.038
-0.040
-0.042
-0.044
-0.046
-0.048
-0.050
-0.052
-0.054
-0.056
-0.058
-0.060
-0.062
-0.064
-0.066
-0.068
-0.070
-0.072
-0.074
1600
1590
1580
1570
1560
1550
1540
1530
1520
1510
Wavenumbers (cm-1)

Figure 6d

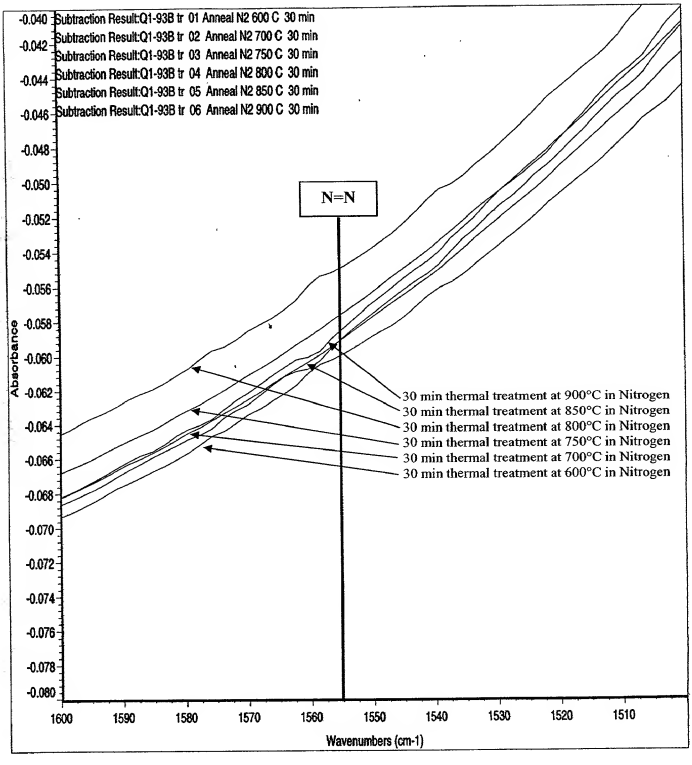


Figure 7a

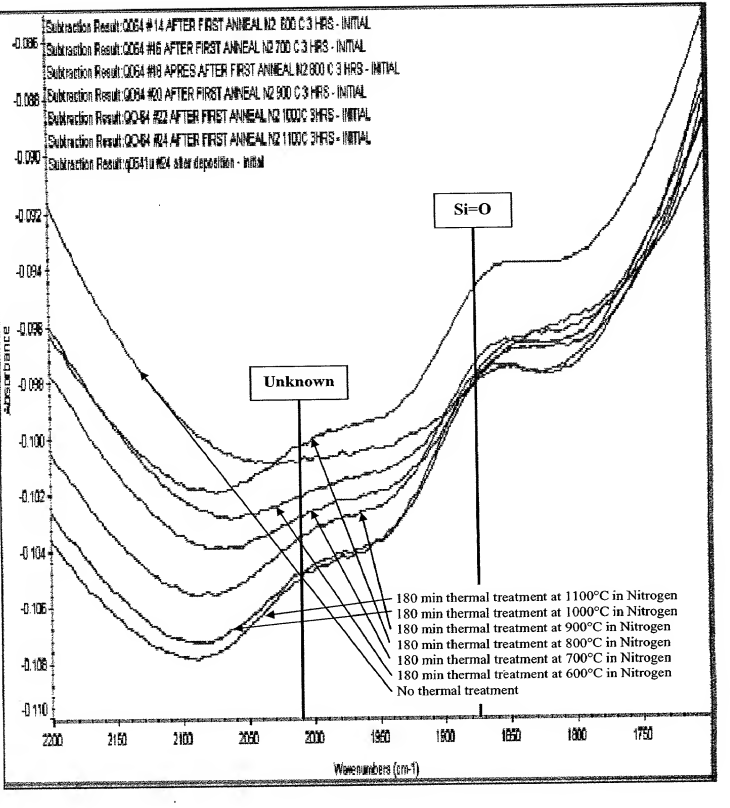


Figure 7b

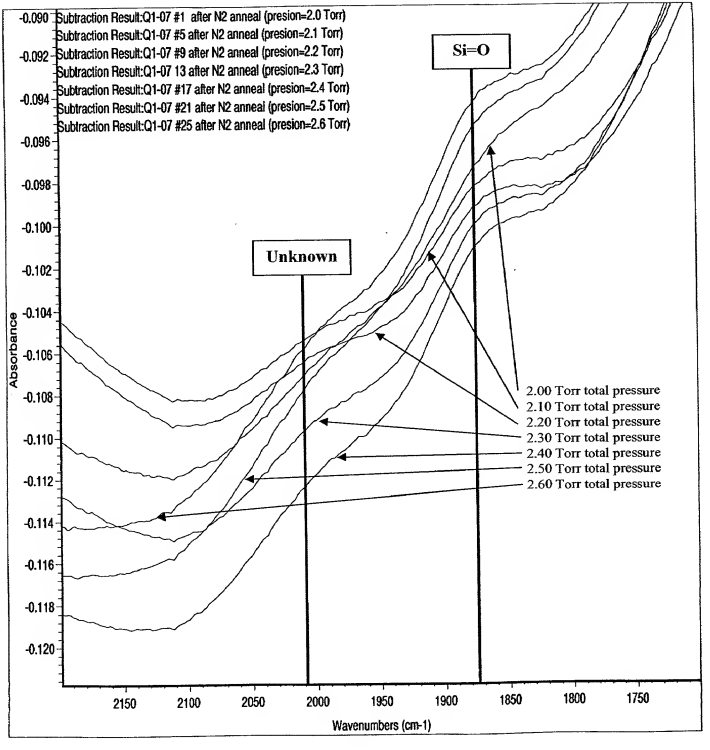

Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
Si=O
Unknown
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
Absorbance
-0.090
-0.092
-0.094
-0.096
-0.098
-0.100
-0.102
-0.104
-0.106
-0.108
-0.110
-0.112
-0.114
-0.116
-0.118
-0.120
2150
2100
2050
2000
1950
1900
1850
1800
1750
Wavenumbers (cm-1)

Figure 7c

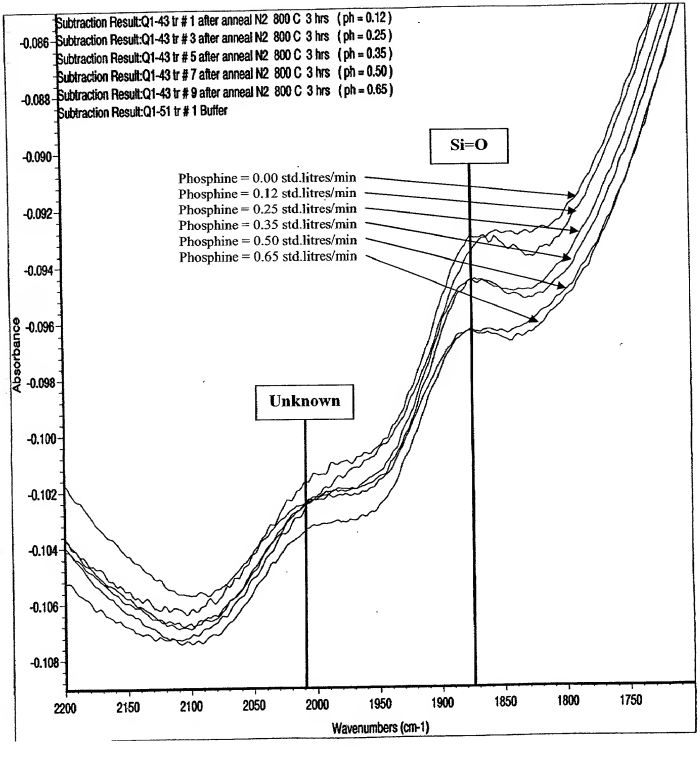


Figure 7d

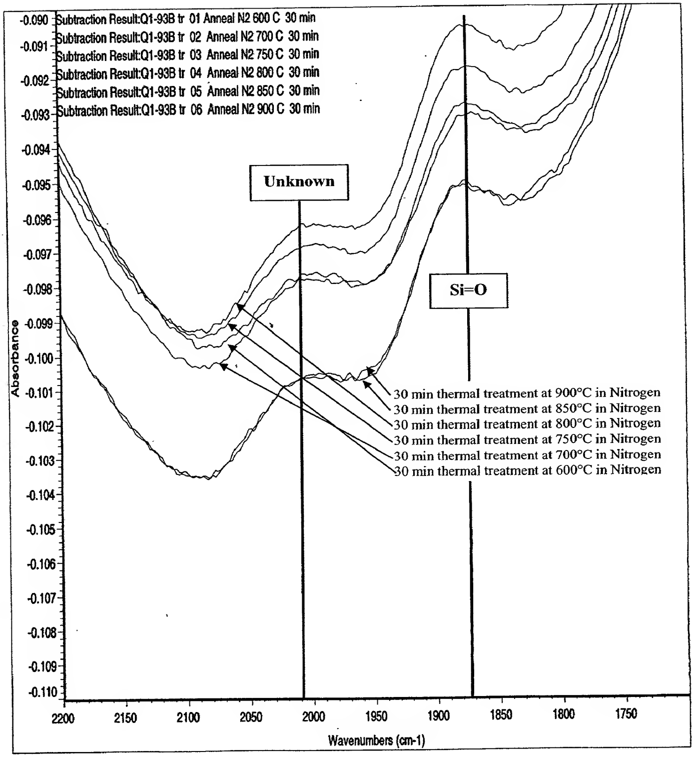


Figure 8a

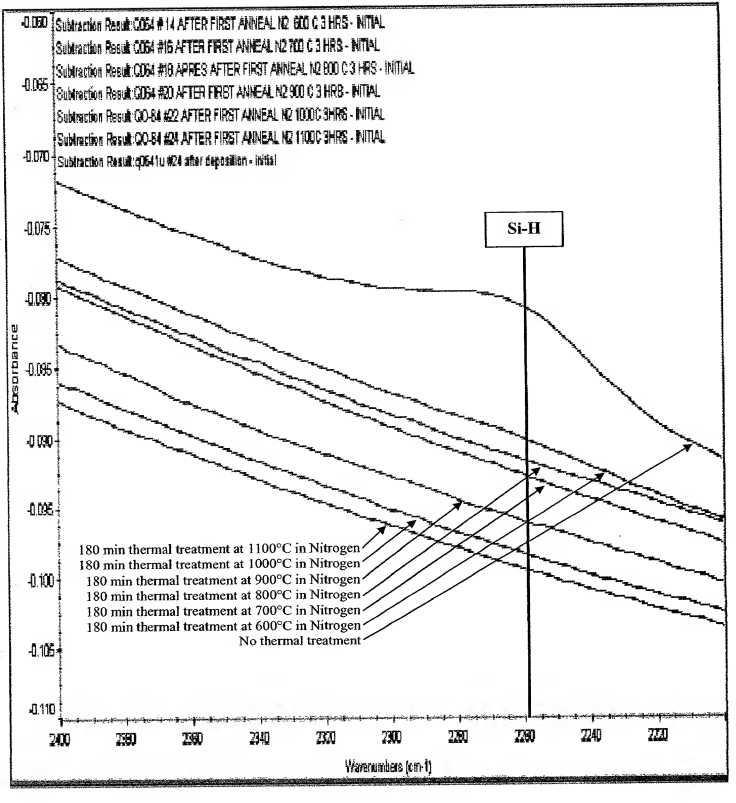


Figure 8b

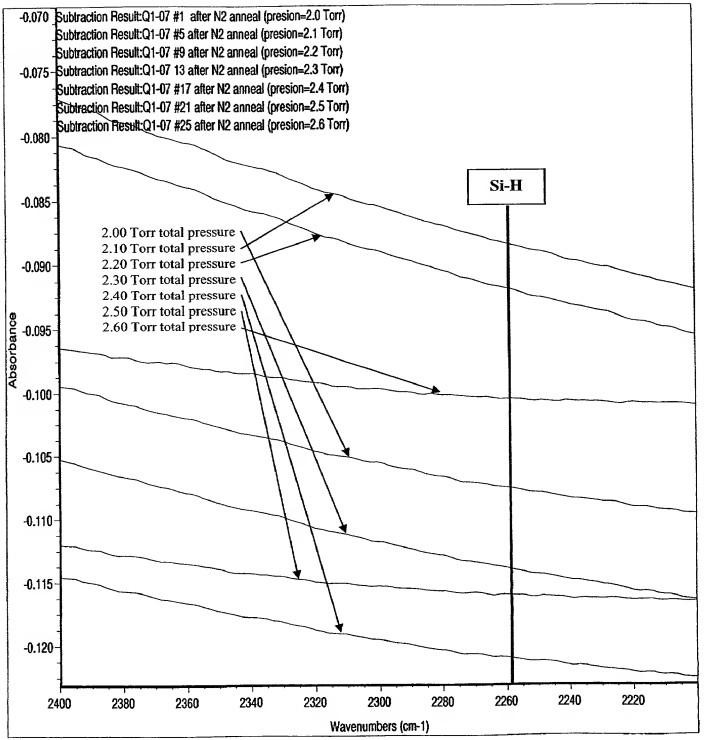


Figure 8c

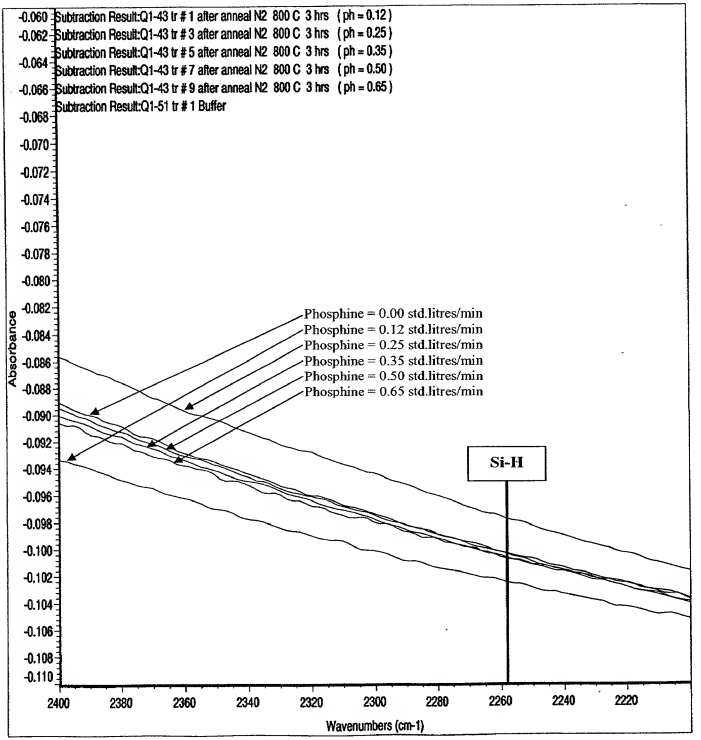


Figure 8d

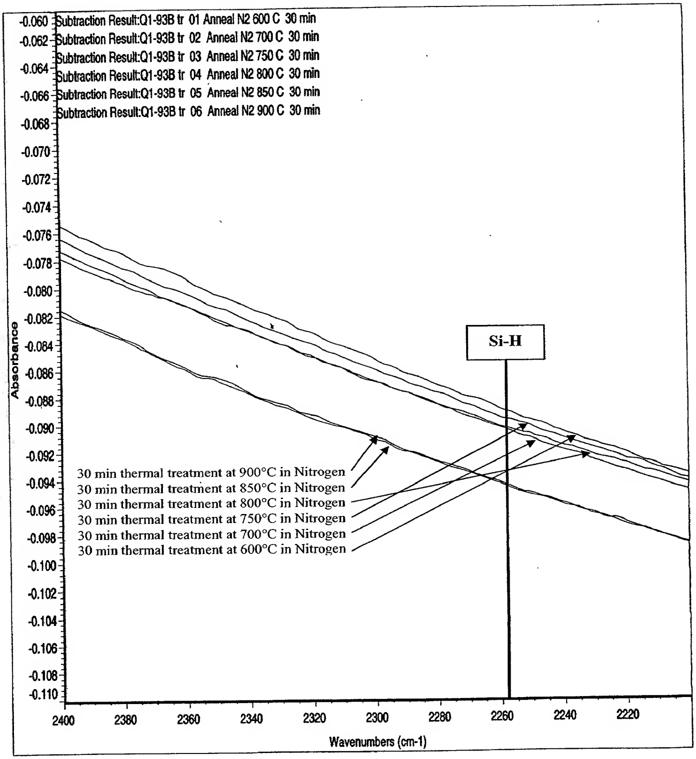


Figure 9a

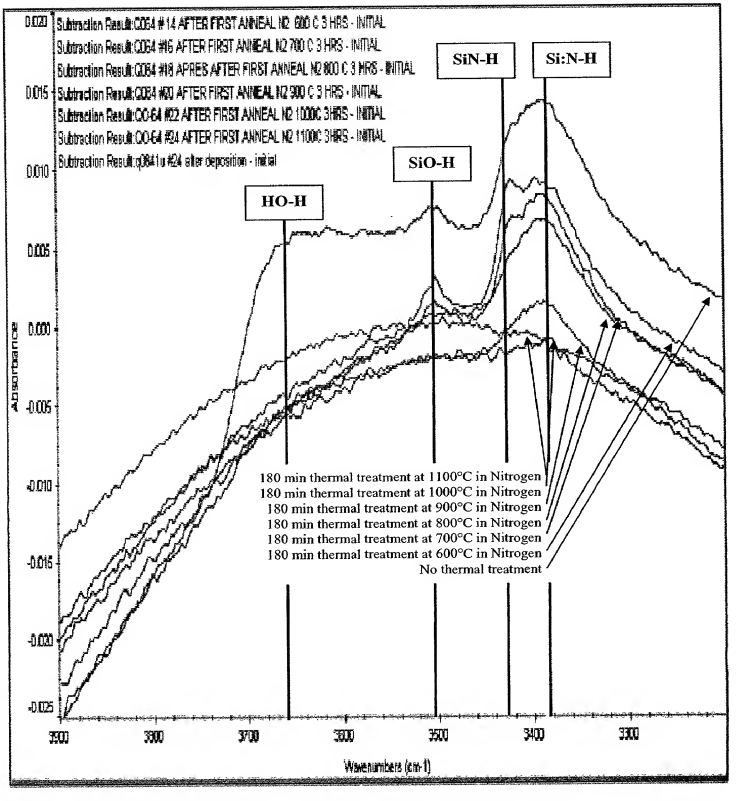
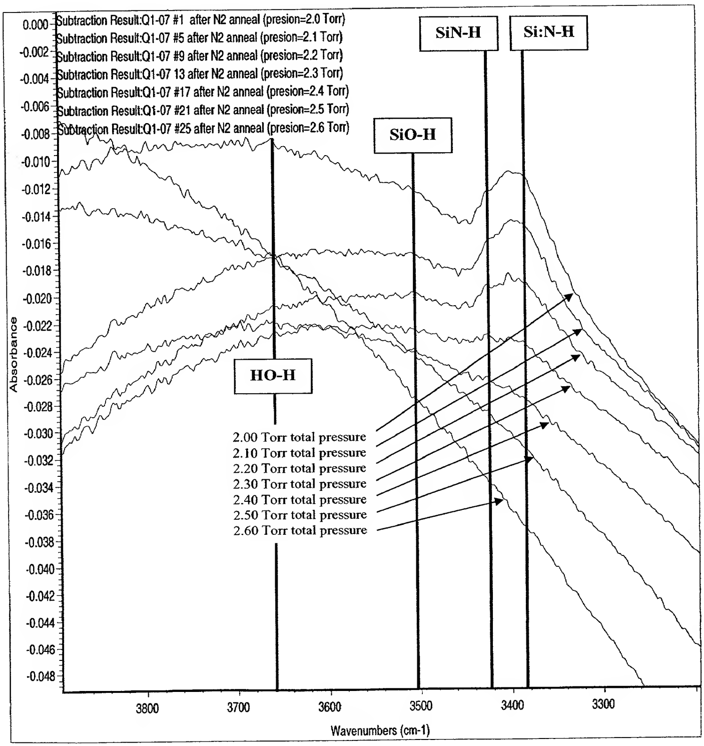

Subtraction Result:C064 # 14 AFTER FIRST ANNEAL N2 600 C 3 HRS - INITIAL
Subtraction Result:C064 #16 AFTER FIRST ANNEAL N2 700 C 3 HRS - INITIAL
Subtraction Result:C064 #18 APRES AFTER FIRST ANNEAL N2 800 C 3 HRS - INITIAL
Subtraction Result:C064 #20 AFTER FIRST ANNEAL N2 900 C 3 HRS - INITIAL
Subtraction Result:CO-64 #22 AFTER FIRST ANNEAL N2 1000C 3HRS - INITIAL
Subtraction Result:CO-64 #24 AFTER FIRST ANNEAL N2 1100C 3HRS - INITIAL
Subtraction Result:c0641u #24 after deposition - initial
SiN-H
Si:N-H
SiO-H
HO-H
180 min thermal treatment at 1100°C in Nitrogen
180 min thermal treatment at 1000°C in Nitrogen
180 min thermal treatment at 900°C in Nitrogen
180 min thermal treatment at 800°C in Nitrogen
180 min thermal treatment at 700°C in Nitrogen
180 min thermal treatment at 600°C in Nitrogen
No thermal treatment
Absorbance
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
3500
3600
3700
3800
3500
3400
3300
Wavenumbers (cm-1)

Figure 9b



Subtraction Result:Q1-07 #1 after N2 anneal (presion=2.0 Torr)
Subtraction Result:Q1-07 #5 after N2 anneal (presion=2.1 Torr)
Subtraction Result:Q1-07 #9 after N2 anneal (presion=2.2 Torr)
Subtraction Result:Q1-07 13 after N2 anneal (presion=2.3 Torr)
Subtraction Result:Q1-07 #17 after N2 anneal (presion=2.4 Torr)
Subtraction Result:Q1-07 #21 after N2 anneal (presion=2.5 Torr)
Subtraction Result:Q1-07 #25 after N2 anneal (presion=2.6 Torr)
SiN-H
Si:N-H
SiO-H
HO-H
2.00 Torr total pressure
2.10 Torr total pressure
2.20 Torr total pressure
2.30 Torr total pressure
2.40 Torr total pressure
2.50 Torr total pressure
2.60 Torr total pressure
Absorbance
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
-0.018
-0.020
-0.022
-0.024
-0.026
-0.028
-0.030
-0.032
-0.034
-0.036
-0.038
-0.040
-0.042
-0.044
-0.046
-0.048
3800
3700
3600
3500
3400
3300
Wavenumbers (cm-1)

Figure 9c

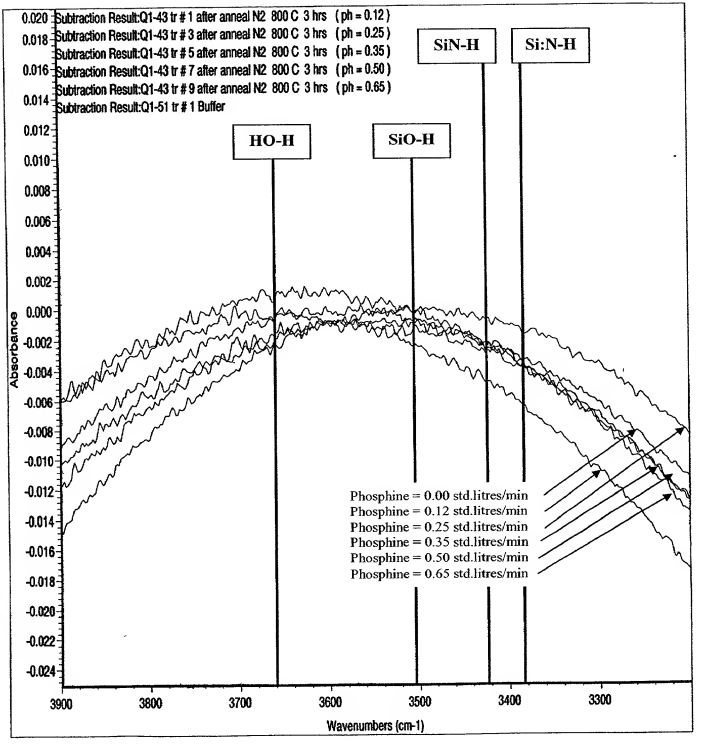

Subtraction Result:Q1-43 tr # 1 after anneal N2 800 C 3 hrs (ph = 0.12)
Subtraction Result:Q1-43 tr # 3 after anneal N2 800 C 3 hrs (ph = 0.25)
Subtraction Result:Q1-43 tr # 5 after anneal N2 800 C 3 hrs (ph = 0.35)
Subtraction Result:Q1-43 tr # 7 after anneal N2 800 C 3 hrs (ph = 0.50)
Subtraction Result:Q1-43 tr # 9 after anneal N2 800 C 3 hrs (ph = 0.65)
Subtraction Result:Q1-51 tr # 1 Buffer
SiN-H
Si:N-H
HO-H
SiO-H
Absorbance
Wavenumbers (cm-1)
Phosphine = 0.00 std.litres/min
Phosphine = 0.12 std.litres/min
Phosphine = 0.25 std.litres/min
Phosphine = 0.35 std.litres/min
Phosphine = 0.50 std.litres/min
Phosphine = 0.65 std.litres/min

Figure 9d

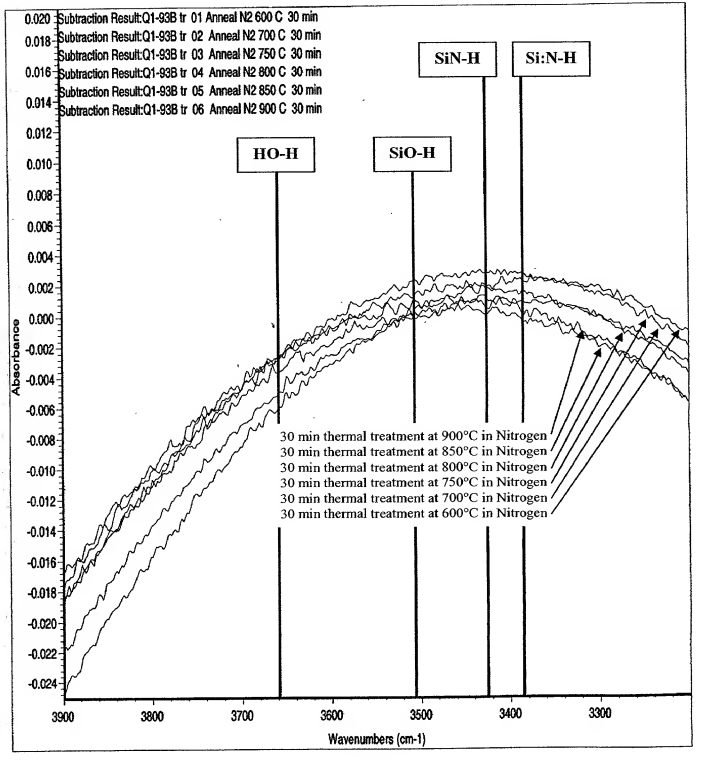
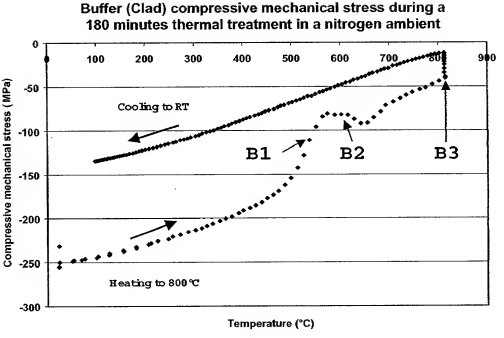


Figure 10


Buffer (Clad) compressive mechanical stress during a
180 minutes thermal treatment in a nitrogen ambient
Compressive mechanical stress (MPa)
Temperature (°C)
Cooling to RT
Heating to 800°C
B1
B2
B3
0
-50
-100
-150
-200
-250
-300
100
200
300
400
500
600
700
800
900

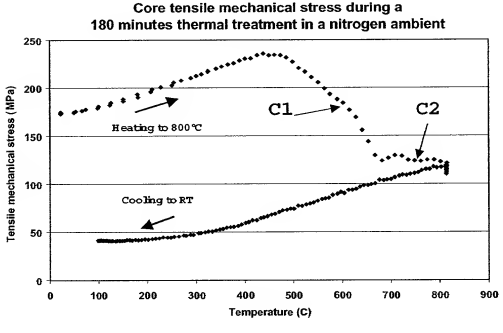

Core tensile mechanical stress during a
180 minutes thermal treatment in a nitrogen ambient
Tensile mechanical stress (MPa)
Temperature (C)
Heating to 800°C
Cooling to RT
C1
C2
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900

Figure 11

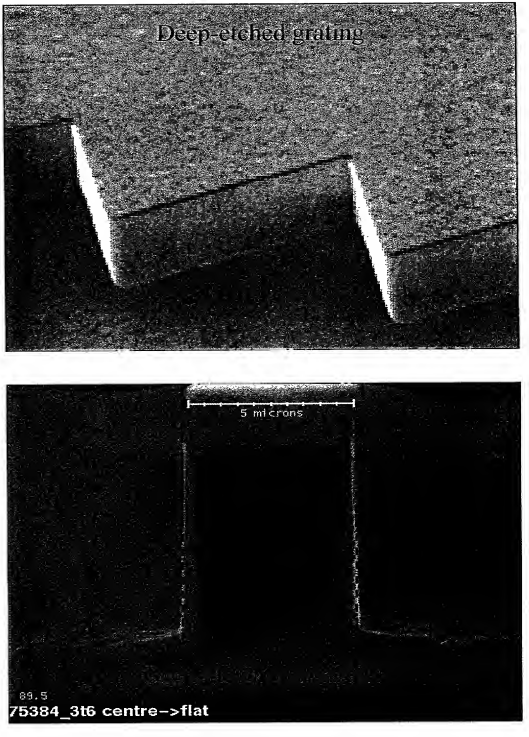


Figure 12

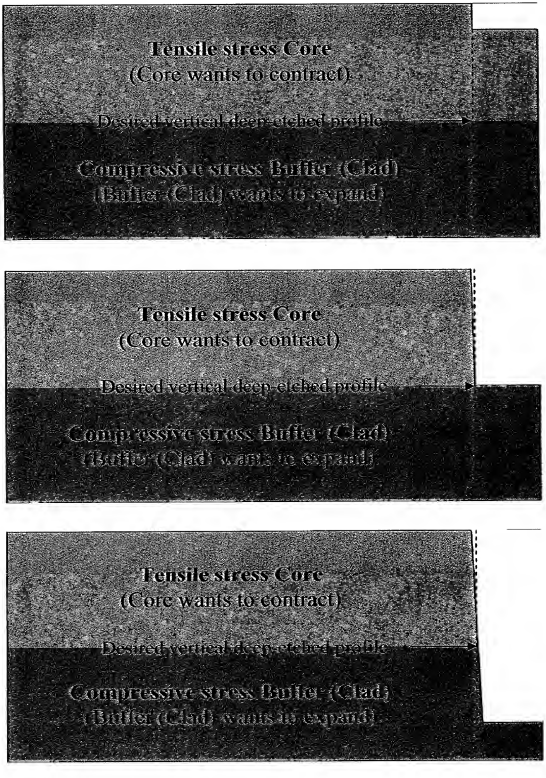


Figure 13

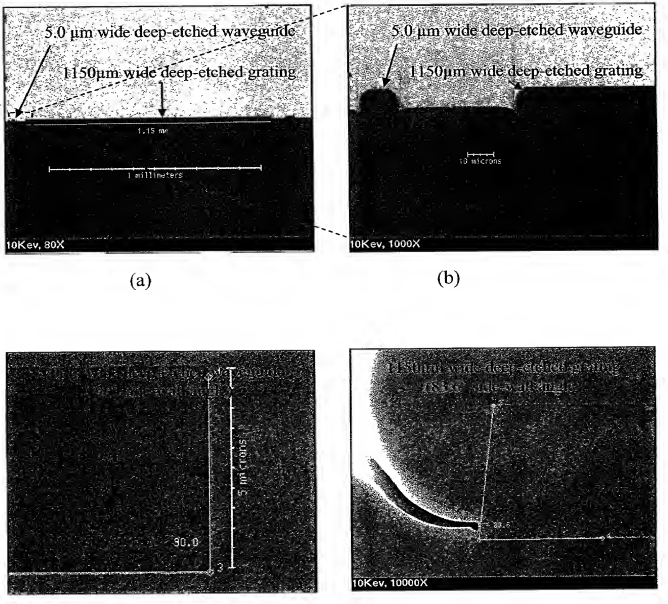
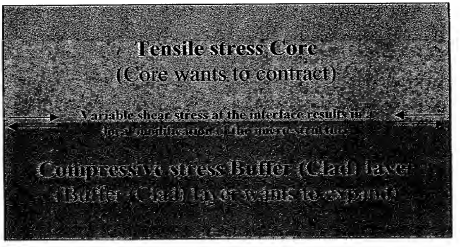
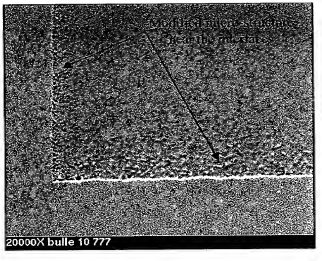

5.0 µm wide deep-etched waveguide
1150µm wide deep-etched grating
1.15 mm
1 millimeters
10Kev, 80X
(a)
5.0 µm wide deep-etched waveguide
1150µm wide deep-etched grating
10 microns
10Kev, 1000X
(b)
5 microns
30.0
(c)
10Kev, 10000X
(d)

Figure 14





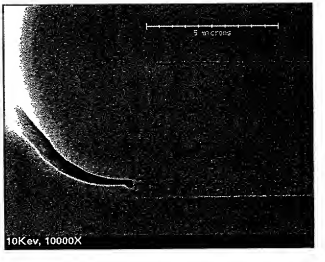


Figure 15

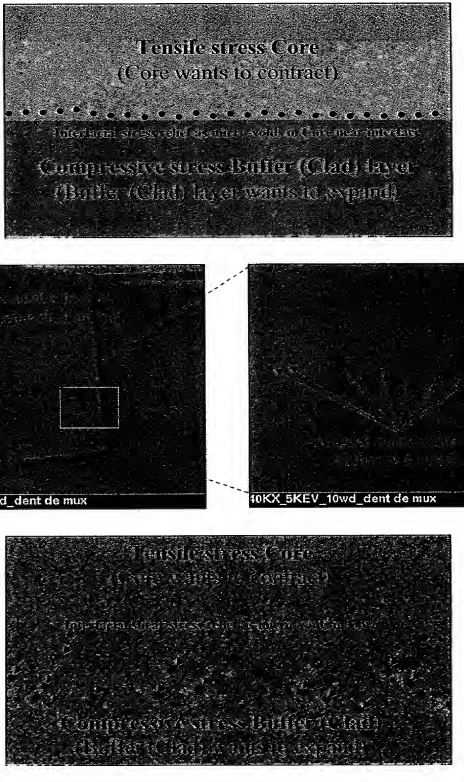


Figure 16

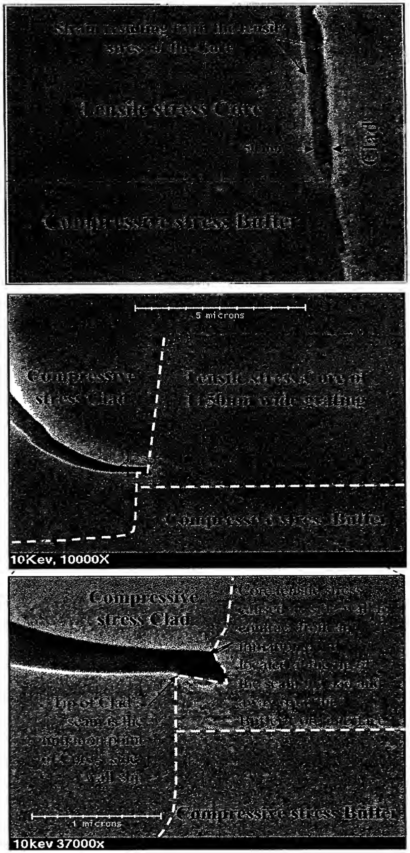
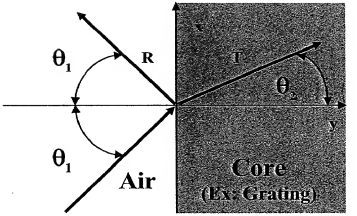
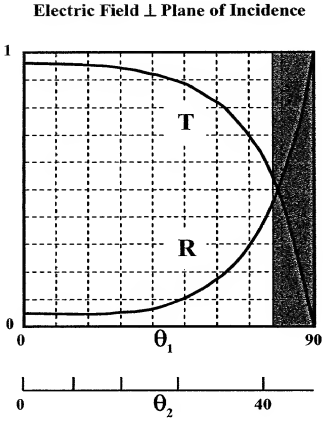

Compressive stress Buffer
5 microns
Compressive stress Clad
Compressive stress Buffer
10Kev, 10000X
Compressive stress Clad
Compressive stress Buffer
1 microns
10kev 37000x

Figure 17





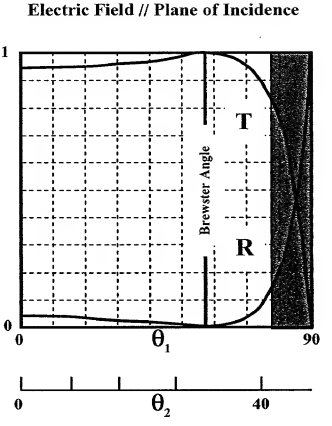
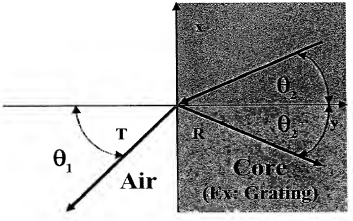
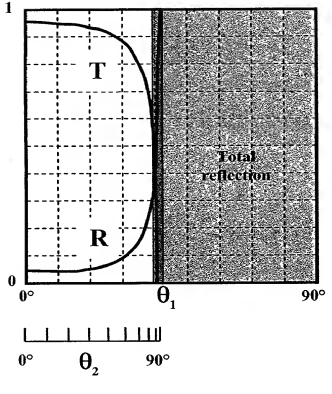


Figure 18



Electric Field ⊥ Plane of Incidence



Electric Field // Plane of Incidence